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An Analysis of Environmental and Biotic Factors Affecting Catch Per Unit Effort of Kankakee River Fishes

Aquatic Biology Section
Technical Report

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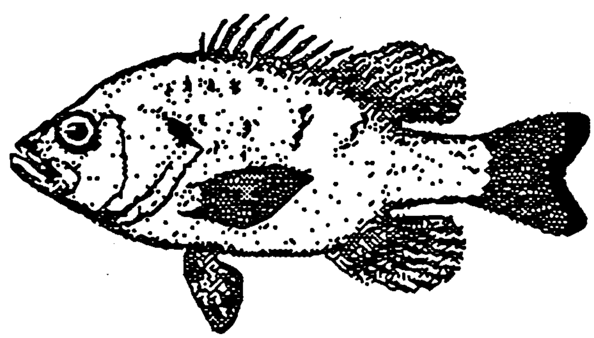

Aquatic Biology Technical Report 87/09

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An Analysis of Environmental and Biotic Factors Affecting Catch Per Unit Effort of Kankakee River Fishes

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INTRODUCTION

Long-term data sets have been critical components in many advances in ecology. Long-term ecological studies provide society with critical data on practical issues, contribute to the development and testing of ecological theory, add to general ecological knowledge, and provide education and training to students and the public (Strayer et al. 1986). Long-term studies are rare, however, due to constraints by funding, personnel, and institutions. A long-term data set of the fish community of a Midwestern warmwater stream is given additional attention and analysis in this report.

Construction of the Braidwood Nuclear Generating Station and its associated riverside intake and discharge structures by Commonwealth Edison Company has provided us the opportunity to study the fish community of the Kankakee River. The Illinois Natural History Survey began a series of fishery surveys in the Braidwood Station Aquatic Monitoring Area in 1977. Initial studies of the Kankakee River were intensive, including quarterly collections of water quality, micro-organisms, benthic invertebrates, and larval, juvenile, and adult fishes (Sule et al. 1978). Annual mid-summer fishery surveys were conducted from 1977 through 1986 (excluding 1980), yielding 9 years of fisheries data (Kwak 1987).

We initiated this study to determine the effects of construction and plant operation on the river. The data gathered thus far are pre-operational. Although the generating station was not operational, the intake and discharge structures were operated on an irregular schedule to test the system and to provide water for the house service water system of the generating station. The generating station is scheduled to begin operations during summer 1987, and a regular pumping schedule will be implemented. Sampling methods and effort have remained constant over the series of collections, which were all completed during the same season. Four more annual fish collections are scheduled during operation of the generating station and riverside pumping facilities, which will provide a data set spanning 13 years.

Monitoring assemblages of fish species and their numerical relationships provides an indication of environmental quality; however, interpretation of results is often difficult and subjective. The goal of this report is to examine environmental factors that may control fish catches and indicate those with significant effects. As our ability to interpret data improves, so will our understanding of the dynamics and ecology of fish communities.

METHODS

Relationships between abiotic parameters and catch of four fish species were examined according to life stage. Selected biotic relationships were also examined. A total of 76 fish species have been collected in the Kankakee River and Horse Creek from 1977 through 1986 in these surveys (Kwak 1987). Constraints of time and effort prohibited detailed study of all species. The species selected encompass a range of species with varying life history, behavior, and niche requirements. The species are smallmouth bass (*Micropterus dolomieui*), rock bass (*Ambloplites rupestris*), golden redhorse (*Moxostoma erythrurum*), and bluntnose minnow (*Pimephales notatus*). Young-of-the-year, juvenile, and adult life stages were studied for all target species, except the bluntnose minnow whose life history precluded the study of a juvenile stage.

Sampling Methods

Boat electrofishing and shoreline seining were used to collect fish in the Kankakee River during late July or early August from 1977 through 1986 (excluding 1980). See Kwak (1987) for a description of sampling locations (Figure 1), equipment, and procedures.

Each electrofishing station was shocked four times, with a 2-day repopulation period between replicates. Seine samples were taken at two sites in each sampling station twice in a 2-week sampling period, representing four replicates per station. One unit of electrofishing effort was quantified as 0.5 hour of electrofishing in a stream reach of approximately 152 meters (500 feet) using a set pattern along a station shoreline. Each shoreline seine haul covered a distance of 15 meters (49 feet) and was considered one unit of seine effort. A total of 40 units of electrofishing effort and 44 units of seine effort were expended during an annual survey. In this report, total catch from each annual survey is used in comparative analyses.

Data Analysis

Although 9 years of annual collections is a rare data set, it provides only nine data points and eight degrees of freedom for correlations or regression analyses. It is tempting to divide these annual data into replicates to increase the degrees of freedom and attain statistical significance more readily. This manipulation, however, is not acceptable. Replication in this case is desirable to increase precision and sensitivity of the sampling program. Replication here refers to additional samples collected, which should be referred to as temporal pseudo- replicates (Hurlbert 1984). A replication of treatment is not inferred. Multiple samples do not increase the number of degrees of freedom available for testing a treatment effect (Hurlbert 1984). In such cases the most appropriate approach is to use a single datum, usually a mean (a sum, in this case).

Frequency distributions for length and weight were calculated for each species each year. Frequency distributions, limited age determination by scale analyses, and data from the literature (Carlander 1969, 1977; Pflieger 1975b; Smith 1979) were the criteria for grouping catch by life stage. Catch by number and weight was also expressed as a proportion of the total catch (relative catch); such a measure minimizes the effects of sampling efficiency and more likely indicates changes in populations regardless of sampling conditions.

Discharge volume and water temperature data for the Kankakee River were obtained from a gauging station in Wilmington, Illinois, operated by the U.S. Geological Survey (U.S. Geological Survey 1976-1986). Water temperature data were not available for any years after 1977. Air temperature was recorded at the City of Kankakee Water Pollution Control Center and was reported by the U.S. National Oceanic and Atmospheric Administration (1976-1986).

A mean daily air temperature was calculated as an average of the daily minimum and maximum. All air temperatures were converted from Fahrenheit to Celsius scale. A cumulative change in mean daily air temperature and discharge was calculated as the summation of the absolute values of the differences in the mean daily temperature or discharge between successive days. The resulting values were included in the analysis to detect variable degrees of stream environmental fluctuations within a time period. A regression analysis was performed using air temperatures from May through June, 1976-1977, as the independent variable and corresponding water temperature as the dependent variable. If a highly significant relationship was found, the use of air temperatures in place of water temperatures in subsequent analyses would be substantiated.

Correlation matrices using paired data from the same year were constructed comparing independent variables (discharge and temperature) to dependent variables (catch), yielding a series of correlation coefficients (r). The natural logarithm (log) transformation of the dependent variables was included in each correlation matrix to detect possible exponential relationships. The results of the correlation matrices were used as an indication of significant relationships between variables. Once a correlation was established, the nature of the relationship was examined and mathematically described through regression analysis. Simple linear regression was performed using two variables, often with one or both variables log transformed. The data set used in this analysis was not large enough to perform multiple regression. Several relationships, however, warranted fitting the data to a quadratic equation (second-degree polynomial). Test statistics (F-test), for testing linearity of the regression function and regression coefficients (r and r^2), were employed to determine the statistical significance (probability) of described relationships. Results were considered statistically significant at $P < 0.05$. Absolute values of correlation coefficients were statistically significant at $P < 0.05$ for nine pairs of data (seven degrees of freedom) when values were greater than $r = 0.666$.

RESULTS

Mean daily water temperature and air temperature during May and June 1976 were positively correlated, and a highly significant linear regression model was constructed ($r^2 = 0.83$, $P < 0.0001$, Figure 2). Confidence limits (95%) for the regression line were small, indicated by narrow confidence bands (Figure 2). A similar relationship existed between air and water temperature in May-June 1977 with wider confidence bands and was also very significant ($r^2 = 0.60$, $P < 0.0001$, Figure 3). These relationships suggest that water temperature in the Kankakee River is dependent upon air temperature; therefore, we used air temperature data during May and June as an index of water temperature. Air temperatures were used in comparative analyses for convenience, rather than converting them to water temperatures.

Dependent variables, including total catch and catch by species and life stage, were compared to independent variables, consisting of various measures of temperature and discharge (Table 1). The simplest, best-fit regression models were constructed for significant relationships between catch and abiotic factors and are presented by species. Correlations between smallmouth bass and rock bass are also examined.

Total Catch

Total abundance of fish from an annual survey was positively correlated to average mean daily air temperature during May and June ($r = 0.72$) but was negatively correlated to mean discharge in the Kankakee River in May-June ($r = -0.63$). Significant regression models were calculated for the relationship between abundance and temperature in May-June ($P = 0.029$, Figure 4) and between abundance and log-transformed discharge in May-June ($P = 0.013$, Figure 5). However, the best predictor of total abundance was a composite value of temperature and discharge in May-June, calculated by dividing temperature by discharge ($P = 0.001$, Figure 6). It must be noted that a composite value, such as the quotient of temperature and discharge, has little if any biological meaning in itself, but it serves as a useful term in predicting the dependent variable (total abundance). The dependency of catch by number on water conditions in spring supports the paradigm that hydrologic conditions during the spawning season are important in fish production.

Total fish biomass was a linear function of discharge in the Kankakee River during the collection period (late July-early August). This significant relationship ($P = 0.002$, Figure 7) describes an increase in catch by weight with increasing discharge. Because large fish comprise most of the biomass in these collections (Kwak 1987), this relation probably describes changes in vulnerability of adults to sampling gears under varying hydrologic conditions. This association may be due, in part, to the inundation of habitat, which serves as a refuge from increased flows as water levels rise. Such habitat includes weed beds, terrestrial vegetation, tree root systems, and rocky substrate, all of which may concentrate fish into main channel border habitats and increase their susceptibility to sampling gear. No other independent variables were significantly correlated with total catch by number or weight.

Smallmouth Bass

Young-of-the-Year. As stream waters warm in the spring, adult smallmouth bass move upstream into tributaries to spawn (Trautman 1981). Water level and temperature affect the timing and duration of nesting (Reynolds 1965, Pflieger 1975a), and also, with water quality and predation, are important in egg and fry survival (Emig 1966, Larimore and Duever 1968, Eipper 1975, Larimore 1975, Pflieger 1975a). Reproductive success of smallmouth bass is the result of a complex interaction of biotic and environmental factors. Several quantitative measures of these factors are significant to survival of young smallmouth bass in the Kankakee River.

Catch by number of young-of-the-year (YOY) smallmouth bass, after log transformation, was negatively correlated to mean discharge during June ($r = -0.69$), discharge from June through the collection period ($r = -0.71$), and discharge from July through the collection period ($r = -0.71$). A linear regression model was constructed using discharge from June through the collection period as the independent variable ($P = 0.031$, Figure 8), although using discharge from July through the collection period as a predictor of catch by number of YOY smallmouth bass was equally significant. A negative relationship between stream discharge and YOY smallmouth bass is consistent with laboratory investigations (Larimore and Duever 1968, Larimore 1975) and field observations (Surber 1942, Cleary 1956, Funk and Fleener 1974, Pflieger 1975a), that post-spawning flooding limits smallmouth bass recruitment. However, moderate water fluctuations are desirable, but their timing and magnitude are critical (Pflieger 1975a).

Pflieger (1975a) observed that an increased water level preceding nesting in a Missouri stream enhanced reproductive success through scouring; the influx of ground water buffered fry and eggs from temperature fluctuations and increased organic input and thereby food production. The log-transformed relative abundance of YOY smallmouth bass in the Kankakee River was positively correlated, although not significantly, with mean discharge in April ($r = 0.63$). The plot of this relationship (Figure 9) shows greater variability in relative catch of YOY with increasing discharge values (heteroscedasticity) even after a log transformation. This may be the result of dependence of recruitment of YOY smallmouth bass on only low discharge volumes in April; other factors may control production and survival when discharge is not limiting. Density of reproductive stock may be a controlling factor of YOY recruitment as suggested by the nearly significant polynomial relationship ($P = 0.076$) between relative abundance of YOY and the sum of relative abundances of juveniles and adults from the previous August collection (Figure 10). No significant relationships were found between weight or relative weight of YOY smallmouth bass and independent variables.

Juvenile. No abiotic factors were significantly related to catch by number of juvenile smallmouth bass. The regression of catch by number of juvenile smallmouth bass with YOY smallmouth bass from the previous August collection was nearly significant as a power (log-log) function (P = 0.096, Figure 11). Year-class dominance, where a successful year's hatch outnumbers that of several preceding and following years, is not unusual in smallmouth bass (Eipper 1975).

Mean air temperature in May-June (P = 0.016, Figure 12) and cumulative daily change in discharge during the collection period (P = 0.017, Figure 13) showed a significant semi-logarithmic relationship with relative abundance of juvenile smallmouth bass. The relative abundance of YOY smallmouth bass from the previous August collection used as a predictor of relative abundance of juveniles resulted in a nearly significant relationship (P = 0.072, Figure 14).

The log-log regression of mean discharge from July through the collection period (P = 0.015, Figure 15) was significantly related to weight of juvenile smallmouth bass. Discharge from July through the sampling period and that from May through the sampling period significantly predicted relative weight of juvenile smallmouth bass. Discharge during collection used as an independent variable yielded a highly significant model (P = 0.008, Figure 16).

Adult. Abundance of adult smallmouth bass was positively correlated to the cumulative change in discharge during the collection period (r = 0.66); this relationship was not significant until the extremely large August 1985 collection was deleted from the data set, which decreased the statistical probability (increasing significance) from 0.055 to 0.0001 (Figure 17). A similar relationship was found between discharge during the sampling period and weight of adult smallmouth bass (Figure 18). These findings suggest that catch of adult smallmouth bass is dependent upon conditions during collection, which may alter sampling efficiency or fish habitat selection. No significant relationship to environmental parameters was discovered for relative abundance of adults. A semi-logarithmic regression using maximum discharge during May and June as the independent variable best accounted for changes in the relative weight of adult smallmouth bass (P = 0.002, Figure 19). This negative relationship suggests that spring peak floods exert a controlling effect on adult smallmouth bass relative to the existing fish community, but the mechanisms of such a relationship are not readily explained.

Rock Bass

Young-of-the-Year. The cumulative daily change in discharge during the collection period was positively and significantly correlated to all measures of catch of YOY rock bass: abundance ($r = 0.86$), relative abundance ($r = 0.92$), weight ($r = 0.80$), and relative weight ($r = 0.73$). Mean temperature in May-June was positively and significantly correlated with abundance ($r = 0.84$), weight ($r = 0.87$), and relative weight ($r = 0.86$) of YOY rock bass, but not relative abundance. The best fit regression model is presented for each measure of catch of YOY rock bass in Figures 20-23; measures of abundance were predicted best by the change in discharge during collection, and those of biomass were most dependent upon temperature in May-June. These analyses were strongly influenced by a greater catch of YOY rock bass in 1977 over that of other years.

Although rock bass are not known to migrate upstream in the spring to spawn, females may concentrate in pools during the spawning season (Trautman 1981). Rock bass and smallmouth bass have similar spawning requirements (Pflieger 1975a), yet based on these findings, survival of young rock bass is apparently dependent upon temperature rather than discharge. The correlation of catch of YOY rock bass to discharges during collection likely results from variation in fish habitat selection or sampling efficiency under changing flow conditions.

Juvenile. The only environmental parameter examined that was significantly correlated with catch of juvenile rock bass was cumulative daily change in air temperature during May and June, which provided significant regression models for measures of abundance, biomass, and relative abundance and biomass (Figures 24-27). All but one model (relative abundance) was curvilinear, suggesting that the catch of juvenile rock bass depends upon temperature during critical periods, which may influence survival either physiologically or indirectly.

No significant relationship was found between abundance or relative abundance of juvenile rock bass and YOY rock bass from the previous year, revealing no evidence of year-class dominance occurring in rock bass which indicates the importance of first year survival in controlling juvenile and adult rock bass abundances.

Adult. Catch by number and weight of adult rock bass was also predicted by the cumulative daily change in air temperature during May and June, but these models were only significant ($P = 0.011$ for abundance, $P = 0.005$ for biomass) as polynomial functions (Figures 28-29). Survival of adults may be similar to that of juvenile rock bass, but there is an optimal range or threshold effect. Semi-log ($P = 0.031$) and log-log ($P = 0.018$, Figure 30) regressions were significant models relating relative weight of adult rock bass to the cumulative change in air temperature during May and June; however, this relationship yields more statistical significance as a polynomial.

The relative abundance of adult rock bass was positively correlated to mean river discharge from July through the sampling period ($r = 0.83$), yielding a significant linear model ($P = 0.006$, Figure 31), indicating catch is dependent on sampling conditions.

Smallmouth Bass-Rock Bass Interactions

The timing of a species spawning in relation to that of other species may affect its reproductive success, either by direct competition for nesting sites or by indirect competition for food by young fish (Pflieger 1975a). Pflieger (1975a) suggested that smallmouth bass reproduction may be influenced by other centrarchids, namely rock bass, because of their similar requirements and a significant degree of nesting overlap. He noted, however, that rock bass nesting did not reach peak intensity until 2-3 weeks after that of smallmouth bass. We observed smallmouth bass and rock bass nesting simultaneously but never in the same pool or raceway, suggesting that some competition for nest sites exists.

A correlation matrix was constructed to compare catch of smallmouth bass with that of rock bass to detect negative associations between the species. Only one significant, negative correlation was revealed from 36 correlation coefficients. The relative abundance of juvenile smallmouth bass was negatively correlated to that of YOY rock bass (r = -0.75). Probably juvenile smallmouth bass exert a negative impact on young rock bass rather than the reverse, or a mutually competitive relationship may exist. However, little competition may exist between the two species, rather the negative correlation may indicate that these two life stages have differing responses to a specific abiotic controlling factor. Eight correlation coefficients indicated significant positive relations between catches of smallmouth bass and rock bass.

Golden Redhorse

Young-of-the-Year. Because no YOY golden redhorse were collected in three August surveys (1979, 1982, and 1983), it is difficult to determine the influence of environmental factors on this life stage. The analysis is also complicated by a large catch of YOY in 1985 (489 individuals). One year of highly successful reproduction and 8 years of poor reproduction indicates that a threshold effect may be a controlling mechanism or that a combination of several controlling factors is involved. Such a pattern of recruitment is likely to produce year-class dominance in successive annual collections.

Catch of YOY golden redhorse was negatively correlated, as a log-log relationship, with mean daily discharge from May through August. The relationship was statistically significant for catch by number (r = 0.71) (Figure 31) and by weight (r = 0.76) (Figure 32), but the correlation coefficients were slightly below significant values when catch was expressed as relative abundance (r = 0.62) or relative biomass (r = 0.63). Optimal conditions for recruitment of golden redhorse exist when average daily discharge from May through early August is below the range of 2287-2570 cfs, if a threshold effect involving discharge volume is operational.

Juvenile. Catch by number of juvenile golden redhorse was not significantly correlated to any environmental parameter, although the correlation with discharge in

April was nearly significant (r= -0.62). A large collection of juveniles in 1986 (212 individuals) resulted from successful reproduction in 1985, indicating the importance of recruitment of YOY of previous years to juvenile catch. The relative abundance of juvenile golden redhorse in the catch correlated positively (r = 0.75) to minimum mean daily discharge in May and June, resulting in a significant linear model ($P = 0.019$, Figure 33).

Biomass of juvenile golden redhorse was positively correlated with mean discharge during the collection period, and a significant linear model describing the relationship was constructed ($P = 0.013$, Figure 34). No significant relationship to any parameter studied was found for relative weight of juveniles caught. Catch of juvenile golden redhorse probably depends on several interacting factors.

Adult. Catch by number of adult golden redhorse was significantly correlated with minimum mean daily discharge during May and June (r = 0.68), mean discharge during June (r = 0.68), mean discharge from June through the sampling period (r = 0.71), mean discharge from July through the sampling period (r = 0.71), and mean discharge during the sampling period (r = 0.81). The latter correlation is the most significant relationship and is further described by a simple linear model ($P = 0.008$, Figure 35). A similar model describing catch by weight of adults as a function of mean discharge during collection is presented in Figure 36 ($P = 0.009$). Catch by weight of adults was also significantly correlated with minimum mean daily discharge during May and June (r = 0.67).

Relative abundance of adult golden redhorse was significantly correlated with mean discharges from June through the sampling period (r = 0.72) and from July through the sampling period (r = 0.74). The latter, more significant function was described in a linear model ($P = 0.023$, Figure 37). Discharge in April was the only parameter significantly related to catch by weight of adults, expressed as a proportion of the total catch (r = -0.75) and a linear model with a negative slope ($P = 0.018$, Figure 38). Catch of adult golden redhorse may largely depend on discharge volumes associated with sampling, but spring discharge may affect catch to a lesser degree.

Bluntnose Minnow

Bluntnose minnow females reach maturity at age I, and males at age II (Westman 1938); consequently, juvenile bluntnose minnows (age I+ males) were included in the adult life stage analysis.

Young-of-the-Year. Catch of YOY bluntnose minnow was dependent on discharge in the Kankakee River during different periods in spring and summer, depending on the measure of catch considered. Catch by number, biomass, and relative biomass was significantly correlated to mean discharge during May and June and to that from May through the sampling period. These relationships were significant, however, only after the discharges were log transformed. Discharge from May through the sampling period provided the best-fit regression model for each measure of catch: number ($P = 0.006$, Figure 39), biomass ($P = 0.008$, Figure 40), and relative biomass ($P = 0.012$, Figure 41). The variation in relative abundance of YOY bluntnose minnow caught was best explained by mean discharge from July through the collection period (log transformed) ($r = -0.71$). A corresponding significant semi-log regression model was constructed ($P = 0.033$, Figure 42).

No other significant relationships were found between catch of YOY bluntnose minnow and environmental parameters. All relationships between catch and discharge were negative, indicating that YOY bluntnose minnow are vulnerable to high discharge volumes.

Adult. The log-transformed mean discharge during May was negatively correlated to catch by number ($r = -0.69$) and by weight ($r = -0.73$) of adult bluntnose minnow. Descriptive semi-log models are presented for number ($P = 0.042$) in Figure 43 and for weight ($P = 0.024$) in Figure 44. Although no significant relationships were found to explain changes in relative catch of adult bluntnose minnow, relative abundance and relative biomass were almost significantly correlated with cumulative daily change in temperature during May and June ($r = 0.66$). Catch of adult bluntnose minnow does not appear to be related to environmental measures, suggesting that such biotic factors as predation may control densities of adult bluntnose minnow.

DISCUSSION

Exploratory correlations have been used to assess relationships between the environment and reproduction or year-class abundance (Ricker 1975). Such analyses can become complicated, and caution must be exercised in experimental design and interpretation of results. There is the statistical danger that, with the wide range of environmental parameters available including precise selection of season, a high degree of correlation between a parameter during a certain season and year-class abundance may occur by chance (Gulland 1965). Estimates of abundance and measures of environmental factors probably contain a considerable amount of observational variance. The investigator is thereby confronted with the paradox that the more factors he tests, the more likely he is to include the effective ones in his search, but the less likely he is to be able to recognize them (Ricker 1975).

A mitigating measure in selecting environmental factors is to test only those that have a sound biological basis, a provisional hypothesis, or seem likely from gross inspection of data. The factors we tested satisfy one or more of these criteria. Kwak (1987), in a three-way analysis of variance (including covariables) performed on the same data set, found that discharge, mean gauge height, and delta gauge height in the Kankakee River significantly affected electrofishing abundance. Water velocity during sampling significantly affected the biomass of the seine catch, and dissolved oxygen concentrations significantly affected seine catch by number. These initial findings warranted more study of the effect of sampling conditions on catch. Hynes (1970) summarized literature that indicated reproduction and survival of fry, small specimens, and even adults were influenced by fluctuations in discharge and temperature; therefore, we included these factors during different seasons in the analysis.

Once a correlation is established, the nature of the relationship can be examined and mathematically described through regression analysis. If the regression is statistically significant, and other basic assumptions concerning sampling and the data are satisfied (see Zar 1984), the regression model implies a biological dependence and can be used to predict the dependent variable within the range of the independent variable. If there are biological reasons to believe that the described function is true for values outside those observed, then we may cautiously extrapolate that relationship.

The use of correlation analysis to assess the effect of the environment on year-class abundance is inherently difficult because of the limited number of observational pairs available (one per year). In nature we expect several environmental factors to influence fish abundances. If this is true, no one factor will show a significant dependent effect unless many data pairs are available. For example, if two factors equally control abundance, each factor will have a coefficient of determination (r^2) of 0.50 and a correlation coefficient (r) of 0.71; at least 8 pairs of data are needed to establish such a correlation at $P < 0.05$ (Table 2). Similarly, 20 pairs of data are necessary to show a significant correlation between any one factor and abundance if five environmental factors equally influence abundance. Thus, with nine pairs of data, catch measures that are equally affected by more than two factors will not be significantly correlated; however, factors probably do not exert equal control over catch and a dominant influence will be detected.

Despite the difficulties, the relationship between catch and the environment in the Kankakee River, as a general indication of which factors are influential, should be investigated further. It may be useful to add results of the future fish surveys to the correlations developed here to strengthen (or weaken) relationships described and to indicate potential operational effects of the intake and discharge structures. The relation between the environment, fish reproduction and survival, and fish catch will be strengthened only with additional years data.

SUMMARY

1. Mean daily water temperature in the Kankakee River was found to be significantly dependent upon mean daily air temperature during May and June of 1976 and 1977, which allowed for the use of air temperature data in place of water temperature data in subsequent analyses.

2. Total fish abundance from an annual survey was positively correlated to mean air temperature during May and June but was negatively correlated to mean discharge in the Kankakee River in May and June. Total fish biomass was described as a function of mean discharge in the Kankakee River during the sampling period (late July-early August).

3. Negative significant relationships indicate that young-of-the-year smallmouth bass catch is primarily influenced by mean discharge occurring during June through the sampling period, but discharge during April and reproductive stock density may also be interacting factors. Juvenile smallmouth bass catch was significantly correlated to mean air temperature during May and June, change in discharge during the sampling period, and mean discharge from July through the sampling period. Although no significant relationship was discovered, young-of-the-year recruitment of previous years is likely a controlling factor of juvenile smallmouth bass catch. The change in discharge during the sampling period, mean discharge during sampling, and maximum discharge during May and June were factors significantly influencing adult smallmouth bass catch.

4. Young-of-the-year rock bass catch was significantly affected by mean temperature during May and June and change in discharge during the sampling period. Change in air temperature during May and June was the only significant factor examined that explained a significant amount of the variance in juvenile rock bass catch. Catch of adult rock bass was dependent upon change in air temperature during May and June and mean discharge from July through the sampling period.

5. Only one significant, negative correlation was revealed from 36 correlation coefficients resulting from the comparison of measures of smallmouth bass catch to those of rock bass. The relative abundance of juvenile smallmouth bass catch was negatively correlated to that of young-of-the-year rock bass. Eight correlation coefficients indicated significant positive relations between catches of smallmouth bass and rock bass.

6. No young-of-the-year golden redhorse were collected in three August surveys, which added difficulty to determining controlling factors. Discharge from May through the sampling period was the only factor that significantly affected young-of-the-year catch. Results indicate that a threshold effect may be operational in controlling golden redhorse young-of-the-year recruitment. Juvenile golden redhorse catch correlated significantly to the minimum discharge in May and June and mean discharge during the sampling period, but reproductive success of previous years also affects juvenile catch. Adult golden redhorse catch was significantly influenced by various measures of discharge from April through the sampling period, but discharge during collection is likely the dominant effect.

7. Catch of young-of-the-year bluntnose minnow was significantly correlated to measures of mean discharge during spring and summer, but mean discharge from May through the sampling period predicted young-of-the-year catch most significantly. Mean discharge during May was significantly and negatively correlated to adult bluntnose minnow catch, but nearly significant relationships suggest spring temperature is also an important controlling factor.

8. There are many difficulties associated with the experimental design and interpretation of results of exploratory correlation analyses which may be minimized by appropriate measures. These results are useful as a general indication of which factors are influential in controlling catch. It may be useful to add results of the future fish surveys to the correlations developed here to strengthen (or weaken) relationships described and to indicate potential operational effects of the intake and discharge structures.

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Table 1. List of variables included in correlation and regression analyses.

Dependent variables			Independent variables	
Species	Life stage (for each species)	Measure of catch (for each life stage)	Environmental parameter	Dates
Smallmouth bass	Young-of-the-year	Abundance	Mean temperature	May-June
Rock bass	Juvenile	Relative abundance	Delta temperature	May-June
Golden redhorse	Adult	Biomass	Mean discharge	April May
Bluntnose minnow		Relative biomass		May-June May-sampling period
Total catch	–	Abundance		June July-sampling period
		Biomass		Sampling period
			Min. discharge	May-June
			Max. discharge	May-June
			Delta discharge	May-June Sampling period

Table 2. Number of data pairs necessary to establish a significant correlation ($P<0.05$) with differing numbers of equally controlling independent factors operating on a dependent variable.

Number factors	Coefficient of determination (r^2)	Correlation coefficient (r)	Number data pairs
1	1.0	1.0	3
2	0.50	0.71	8
3	0.33	0.57	12
4	0.25	0.50	16
5	0.20	0.45	20

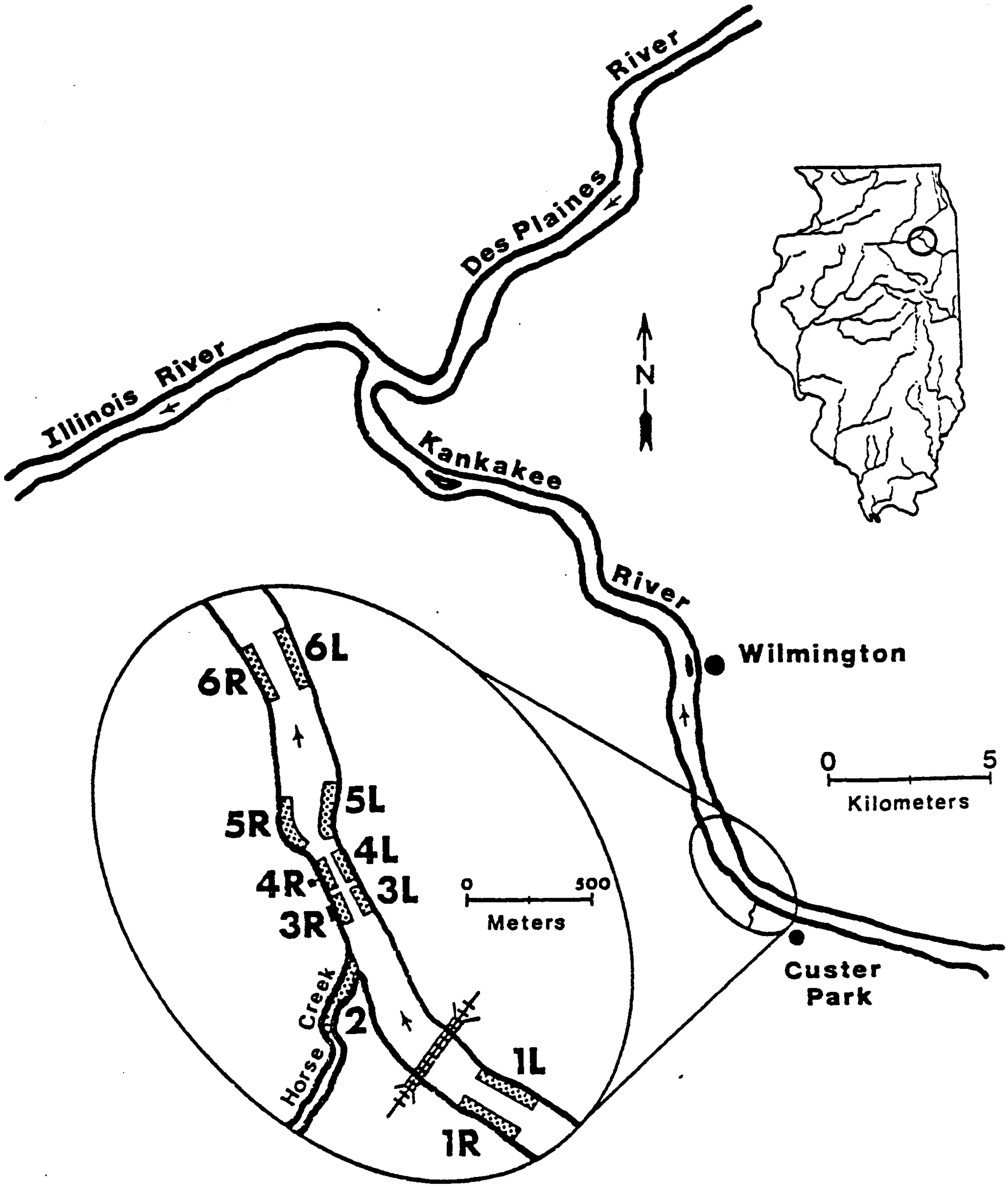

Figure 1. Locations of sampling stations within the Braidwood Station Aquatic Monitoring Area of the Kankakee River.

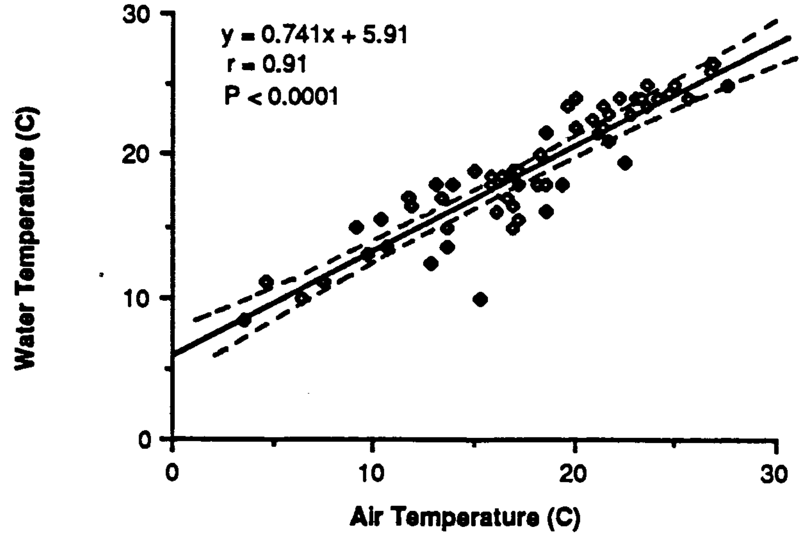

Figure 2. Plot of water temperature versus air temperature during May and June 1976, including 95% confidence belts.

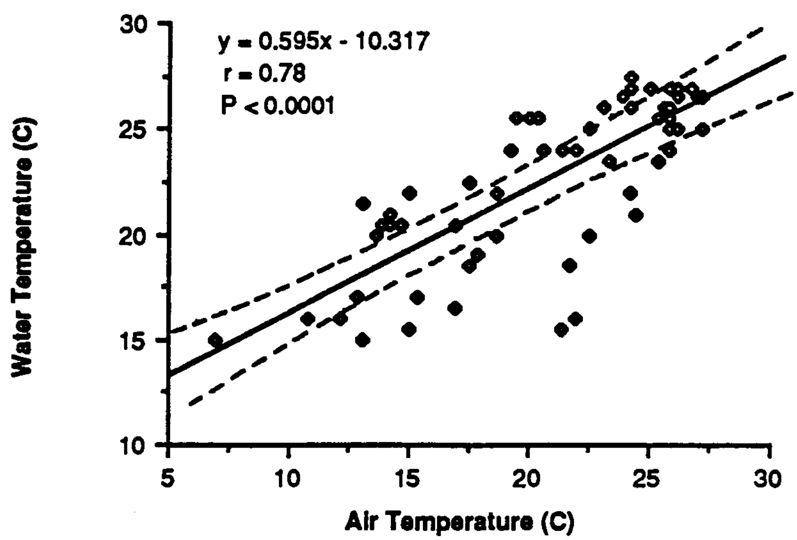

Figure 3. Plot of water temperature versus air temperature during May and June 1977, including 95% confidence belts.

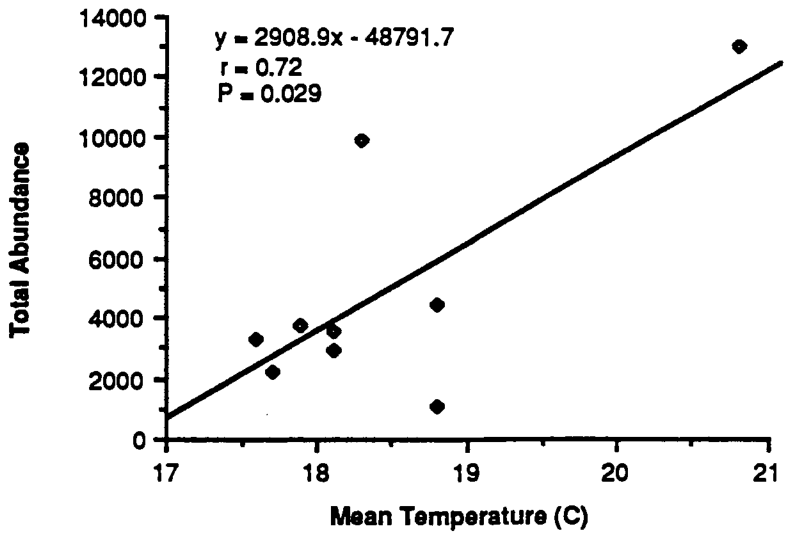

Figure 4. Plot of total fish abundance versus mean air temperature during May and June.

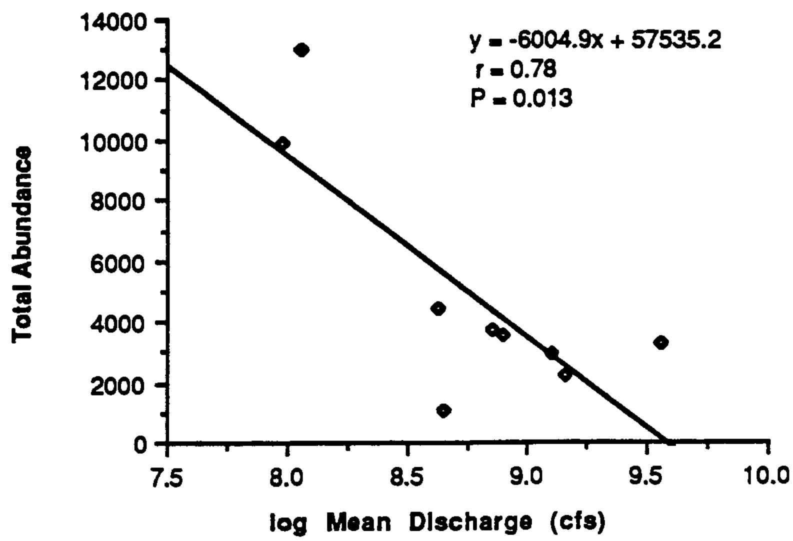

Figure 5. Semi-logarithmic plot of total fish abundance versus mean discharge during May and June.

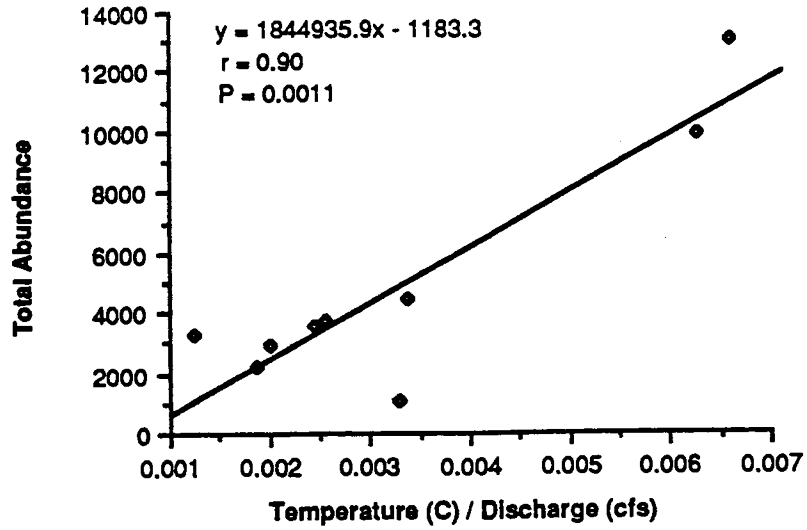

Figure 6. Plot of total fish abundance versus mean air temperature during May and June divided by mean discharge during May and June.

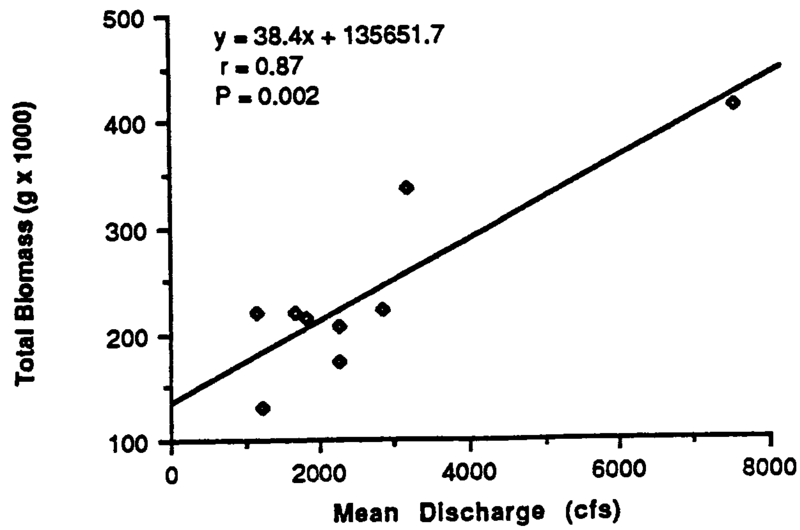

Figure 7. Plot of total fish biomass versus mean discharge during the sampling period.

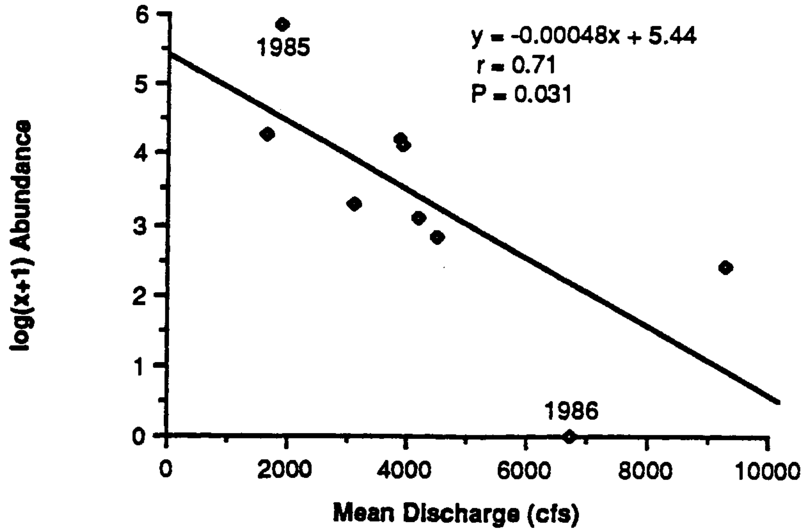

Figure 8. Semi-logarithmic plot of young-of-the-year smallmouth bass abundance versus mean discharge from June through the sampling period.

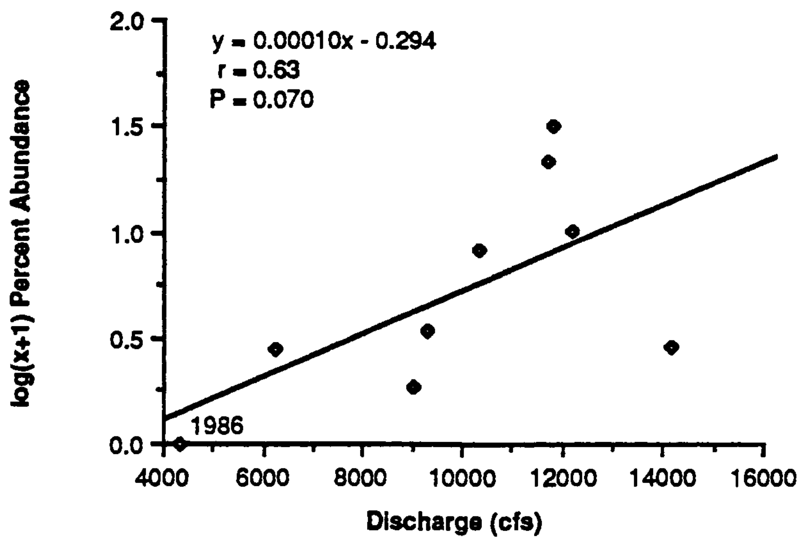

Figure 9. Semi-logarithmic plot of young-of-the-year smallmouth bass relative abundance versus mean discharge during April.

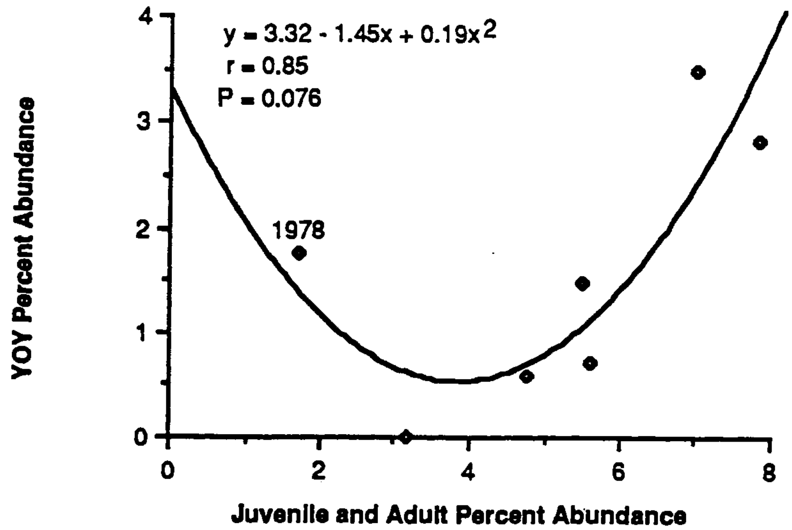

Figure 10. Polynomial regression of young-of-the-year smallmouth bass relative abundance versus juvenile and adult smallmouth bass relative abundance from the previous year.

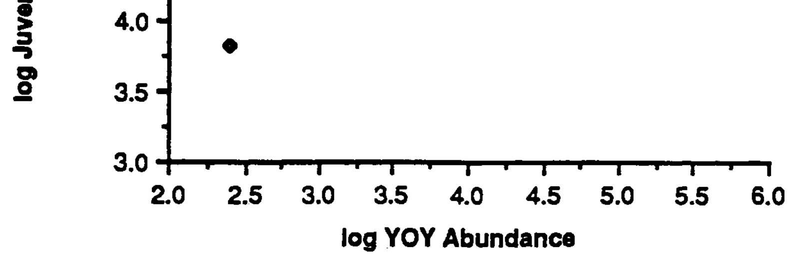

Figure 11. Logarithmic plot of juvenile smallmouth bass abundance versus young-of-the-year smallmouth bass abundance from the previous year.

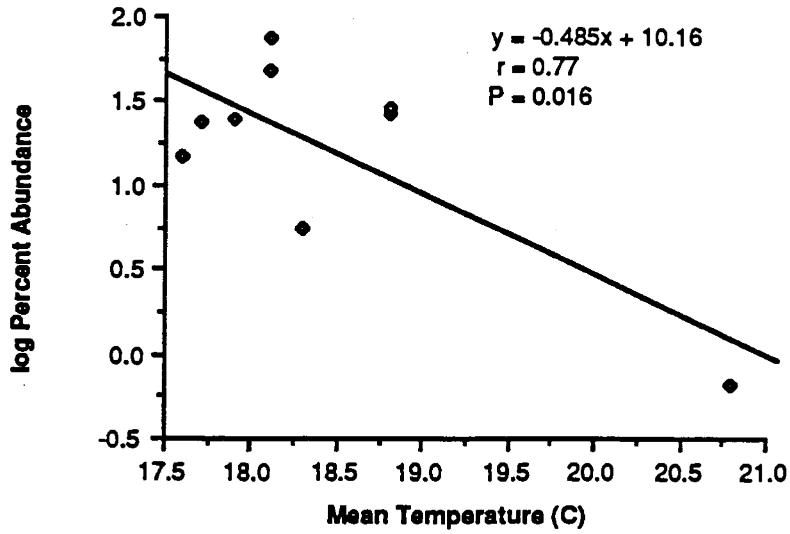

Figure 12. Semi-logarithmic plot of juvenile smallmouth bass relative abundance versus mean air temperature during May and June.

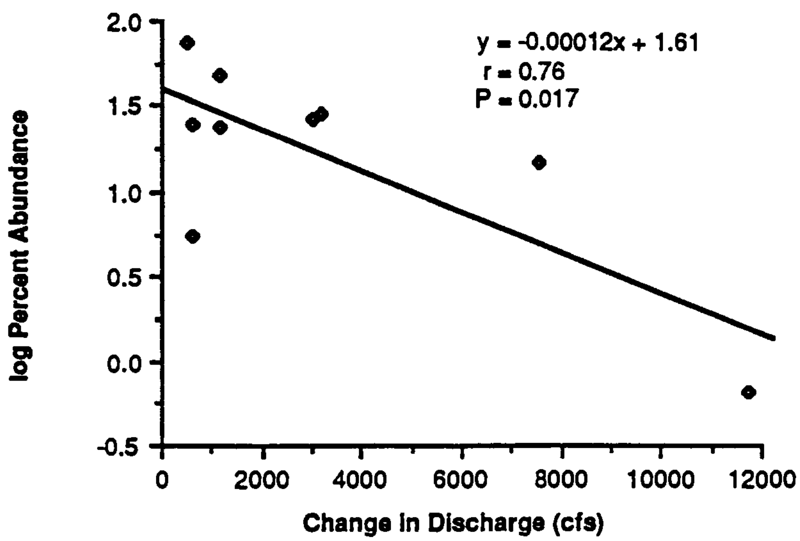

Figure 13. Semi-logarithmic plot of juvenile smallmouth bass relative abundance versus the cumulative change mean daily discharge.

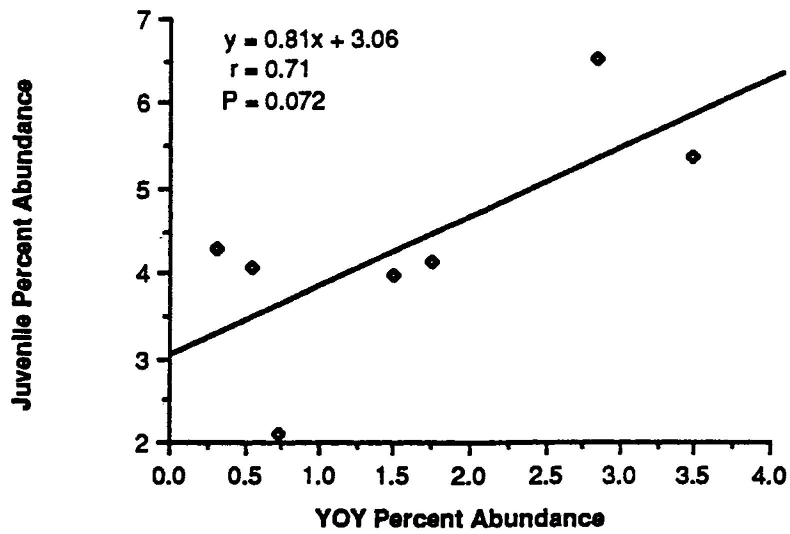

Figure 14. Plot of juvenile smallmouth bass relative abundance versus young-of-the-year smallmouth bass relative abundance from the previous year.

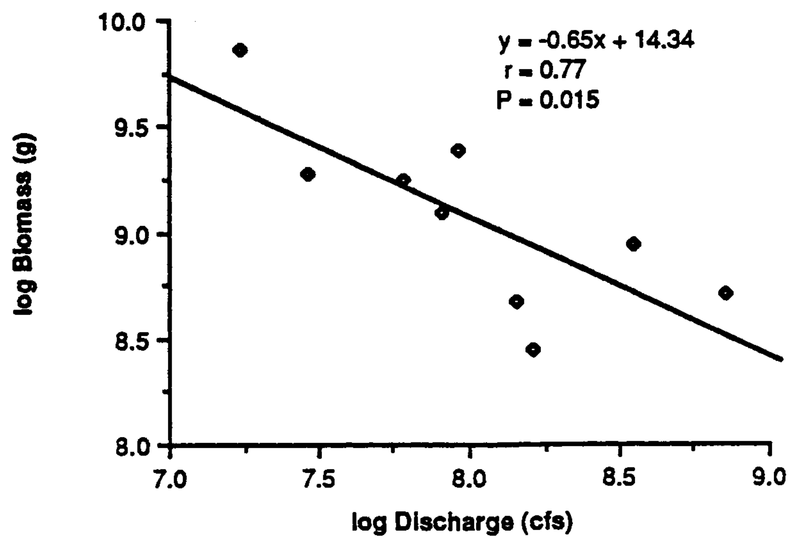

Figure 15. logarithmic plot of juvenile smallmouth bass biomass versus mean discharge from July through the sampling period.

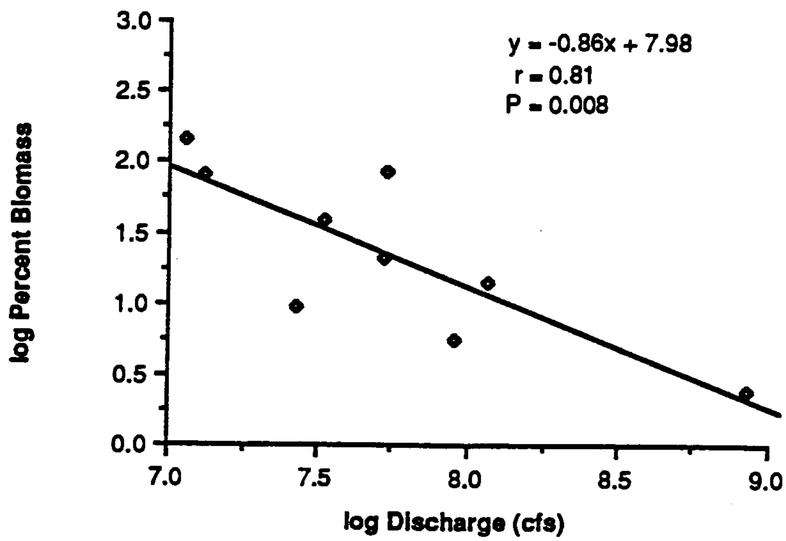

Figure 16. logarithmic plot of juvenile smallmouth bass relative weight versus mean discharge during the sampling period.

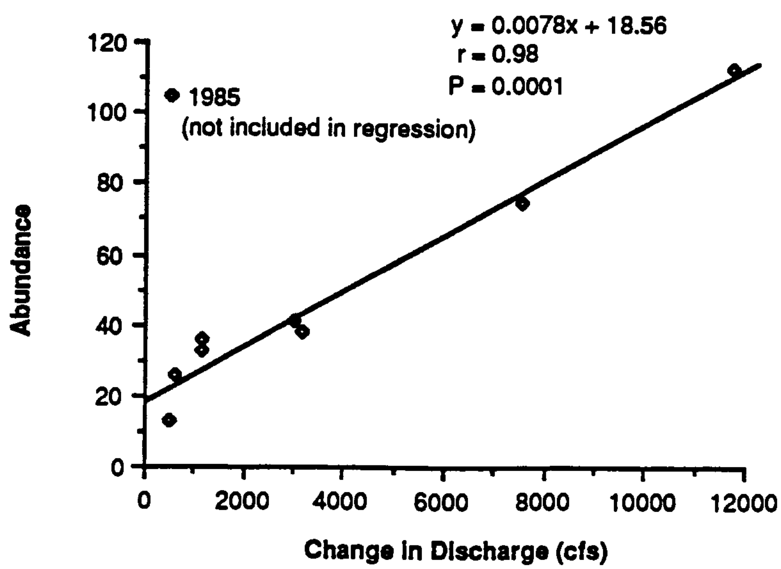

Figure 17. Plot of adult smallmouth bass abundance versus the cumulative change in mean daily discharge during the sampling period.

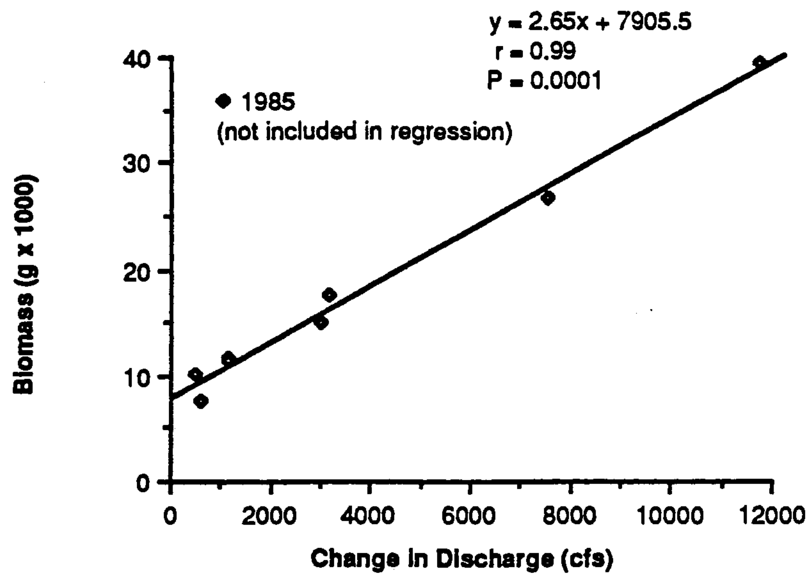

Figure 18. Plot of adult smallmouth bass biomass versus the cumulative change in mean daily discharge during the sampling period.

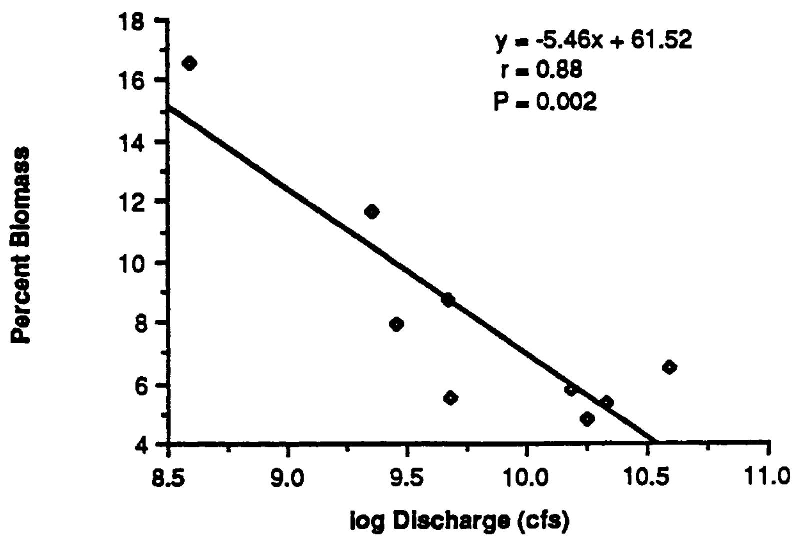

Figure 19. Semi-logarithmic plot of adult smallmouth bass relative weight versus the maximum mean daily discharge during May and June.

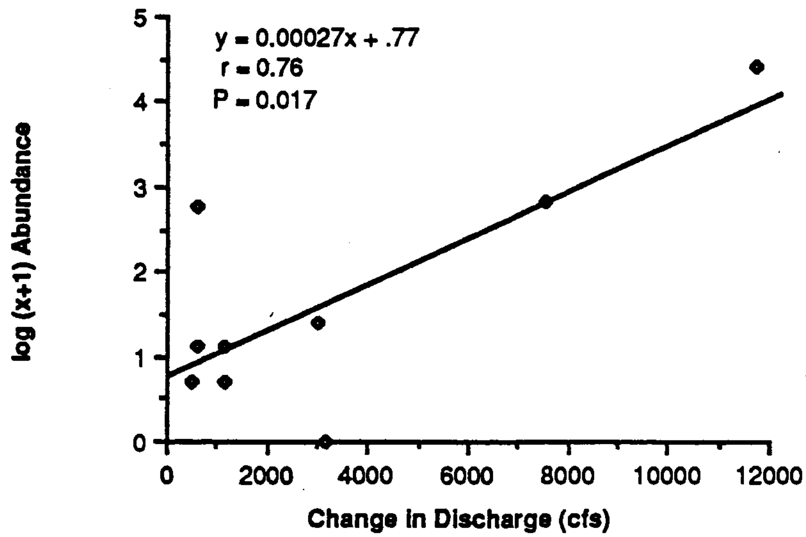

Figure 20. Semi-logarithmic plot of young-of-the-year rock bass abundance versus the cumulative change in mean daily discharge during the sampling period.

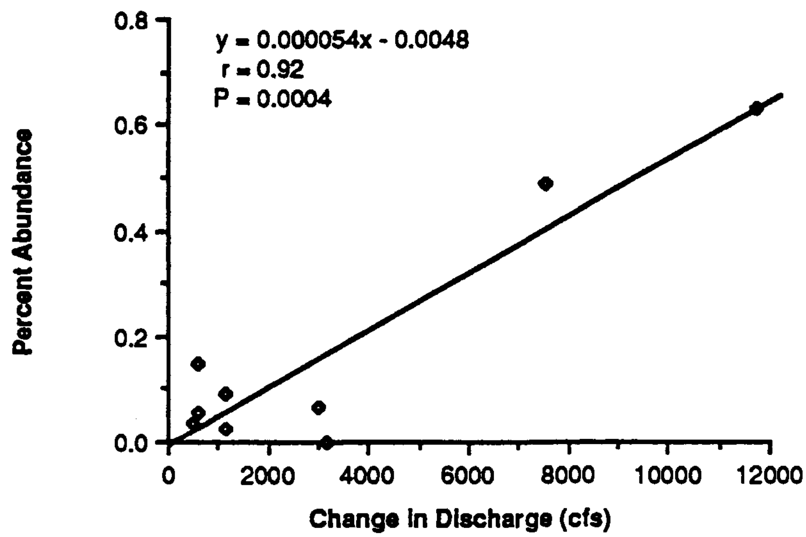

Figure 21. Plot of young-of-the-year rock bass relative abundance versus the cumulative change in mean daily discharge during the sampling period.

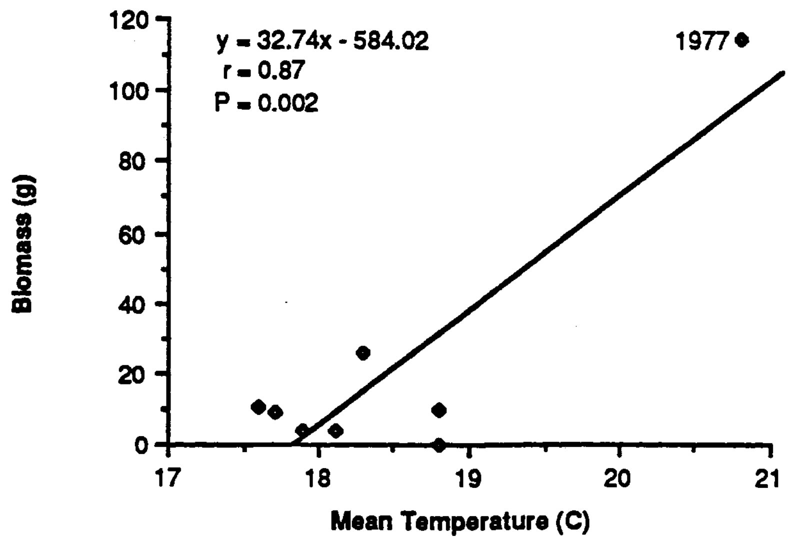

Figure 22. Plot of young-of-the-year rock bass biomass versus mean air temperature during May and June.

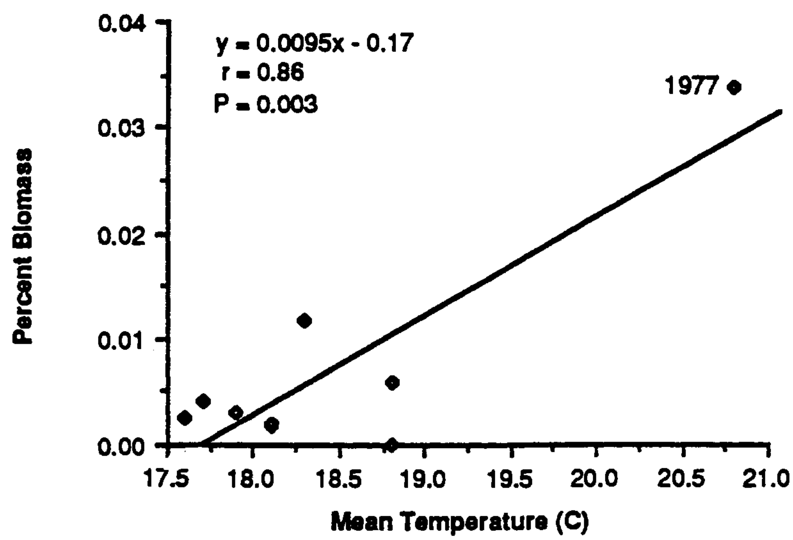

Figure 23. Plot of young-of-the-year rock bass relative biomass versus mean air temperature during May and June.

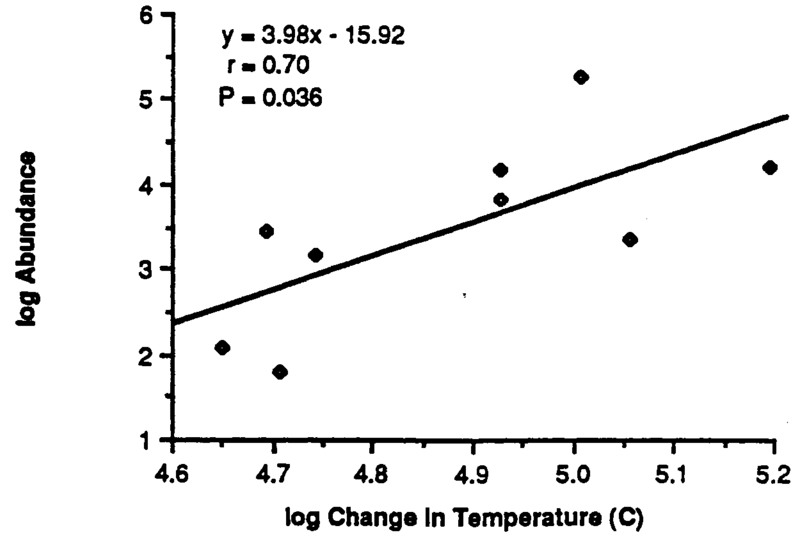

Figure 24. Logarithmic plot of juvenile rock bass abundance versus the cumulative change in mean daily air temperature during May and June.

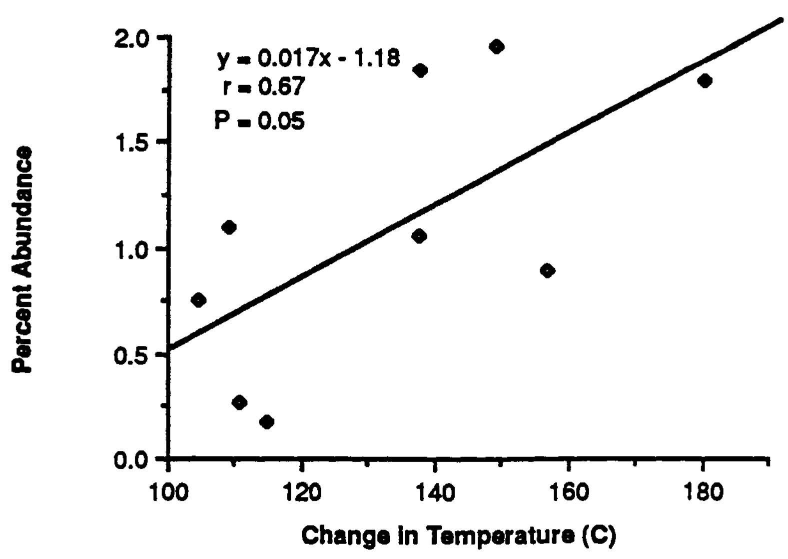

Figure 25. Plot of juvenile rock bass relative abundance versus the cumulative change in mean daily air temperature during May and June.

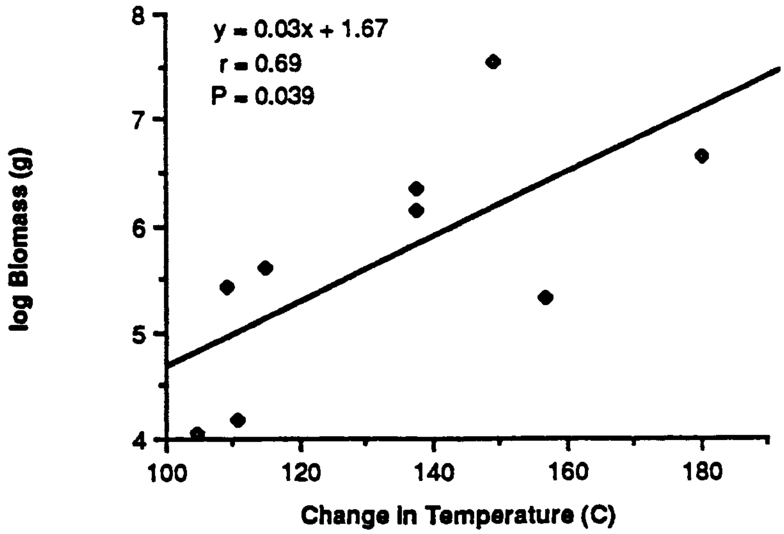

Figure 26. Semi-logarithmic plot of juvenile rock bass biomass versus the cumulative change in mean daily air temperature during May and June.

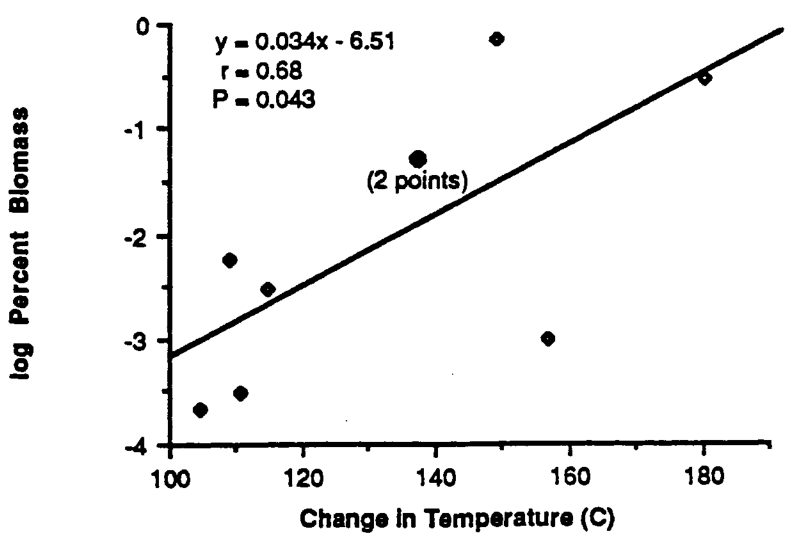

Figure 27. Semi-logarithmic plot of juvenile rock bass relative weight versus the cumulative change in mean daily air temperature during May and June.

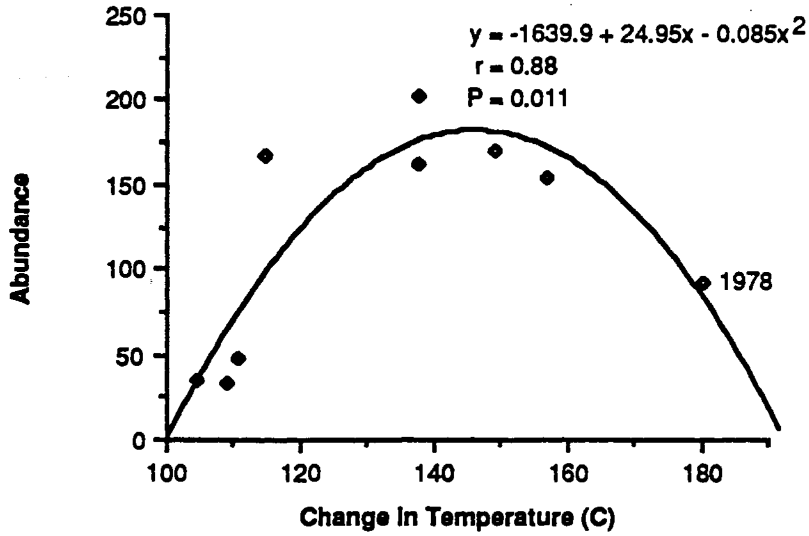

Figure 28. Polynomial regression of adult rock bass abundance versus the cumulative change in mean daily air temperature during May and June.

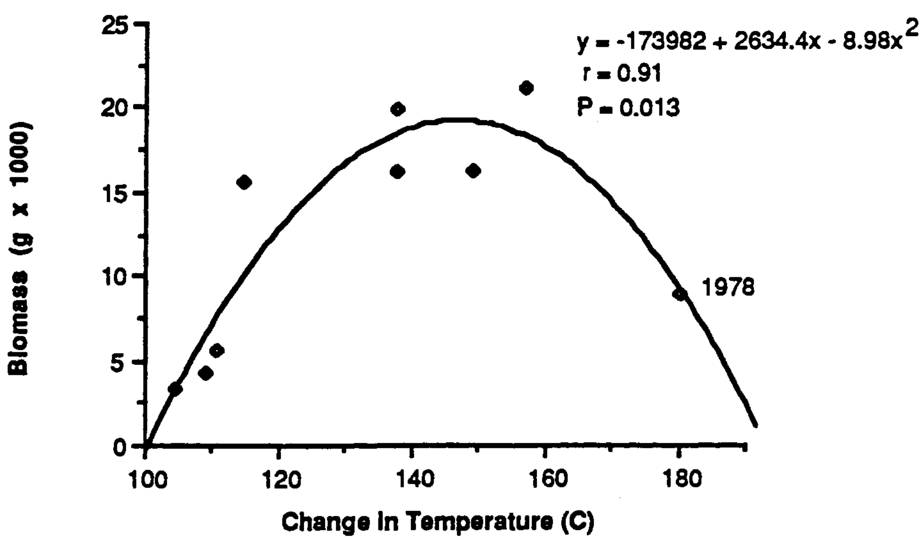

Figure 29. Polynomial regression of adult rock bass biomass versus the cumulative change in mean daily air temperature during May and June.

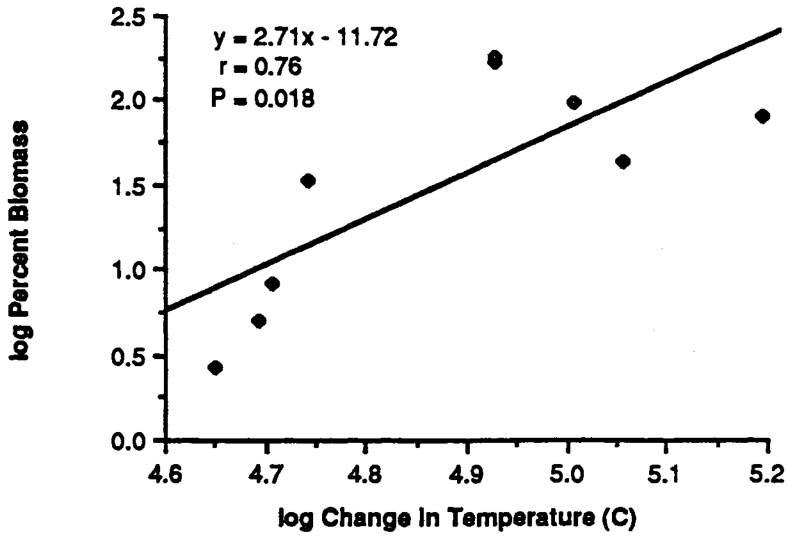

Figure 30. Logarithmic plot of adult rock bass relative weight versus the cumulative change in mean daily air temperature during May and June.

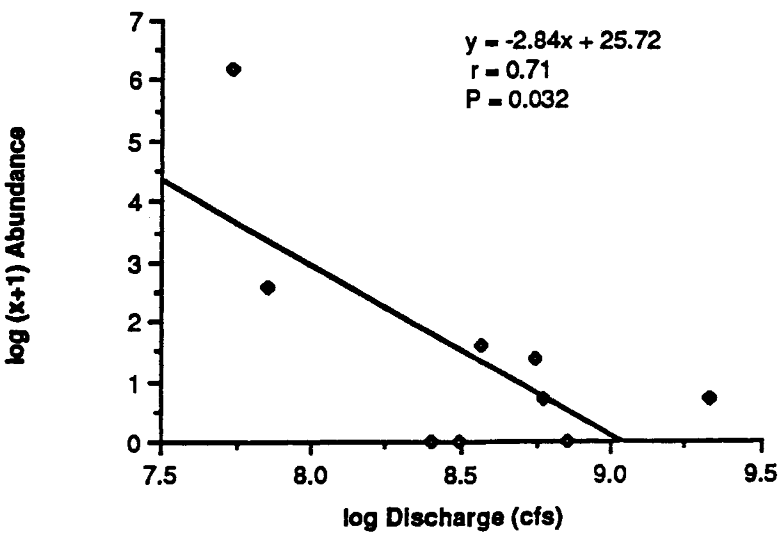

Figure 31. Logarithmic plot of young-of-the-year golden redhorse abundance versus the mean discharge from May through the sampling period.

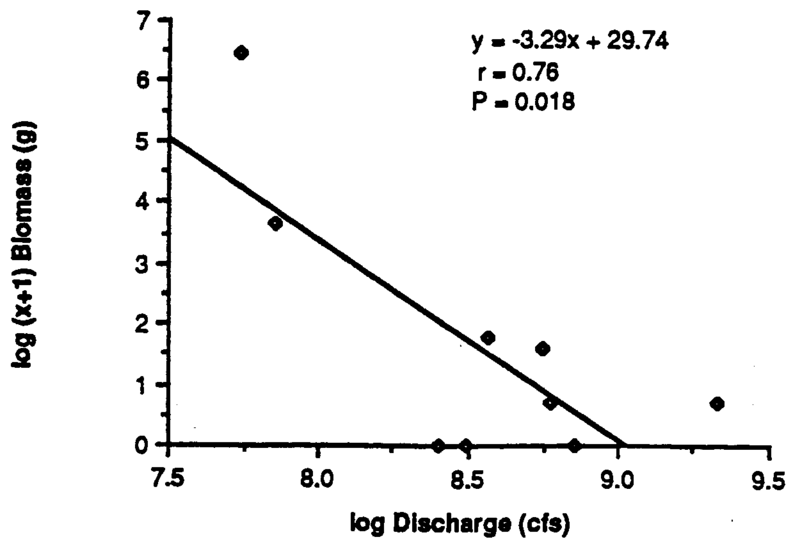

Figure 32. Logarithmic plot of young-of-the-year golden redhorse biomass versus the mean discharge from May through the sampling period.

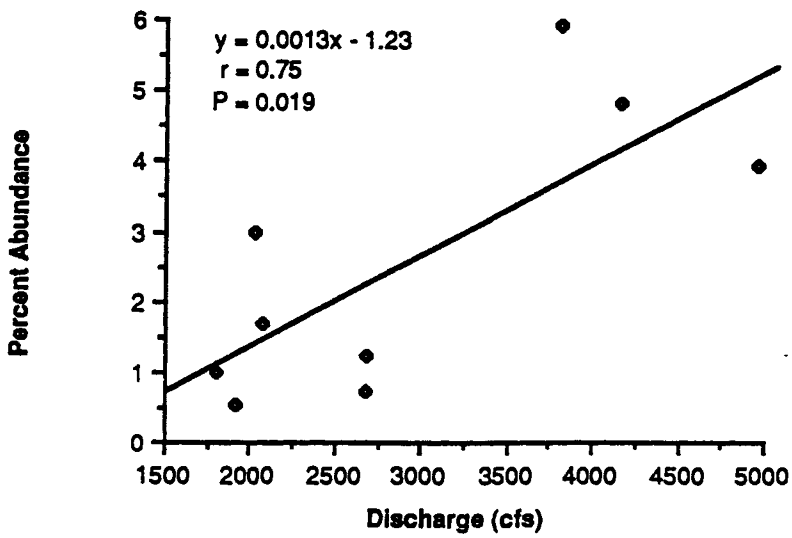

Figure 33. Plot of juvenile golden redhorse relative abundance versus the minimum mean daily discharge during May and June.

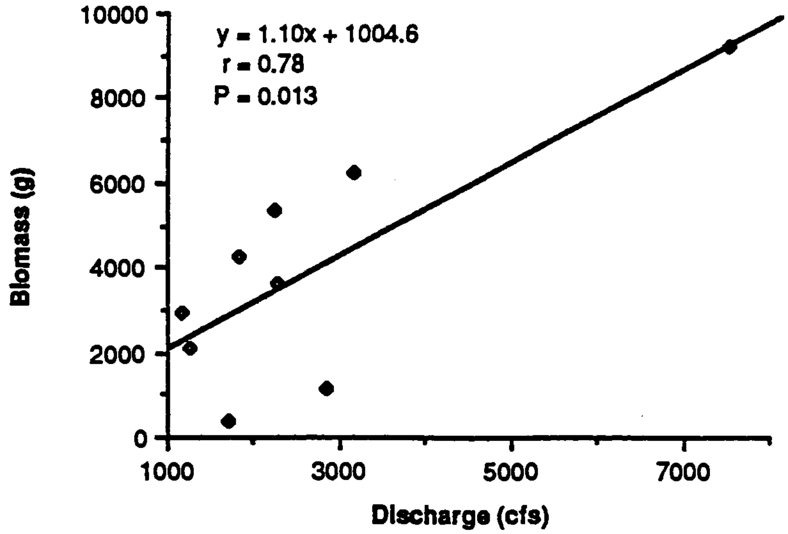

Figure 34. Plot of juvenile golden redhorse biomass versus the mean discharge during the sampling period.

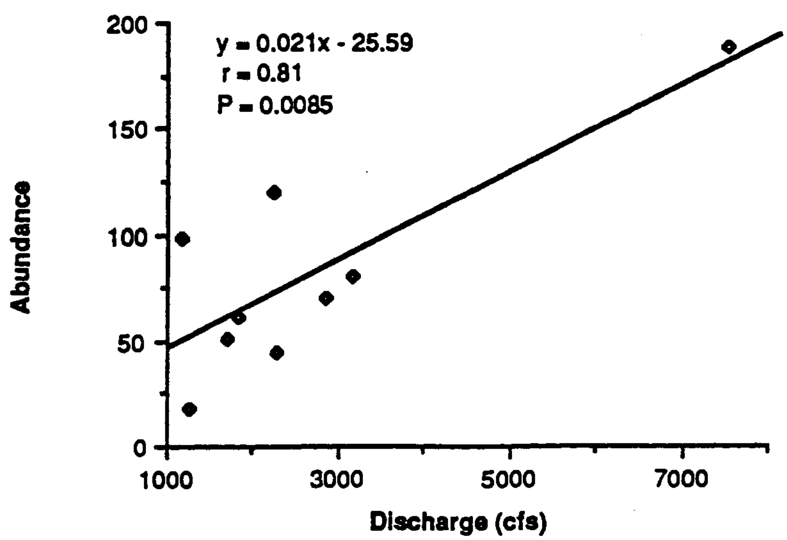

Figure 35. Plot of adult golden redhorse abundance versus the mean discharge during the sampling period.

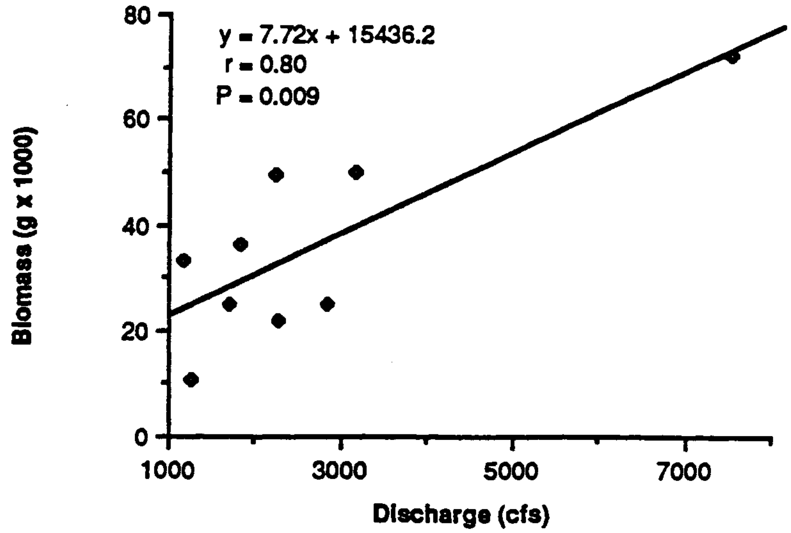

Figure 36. Plot of adult golden redhorse biomass versus the mean discharge during the sampling period.

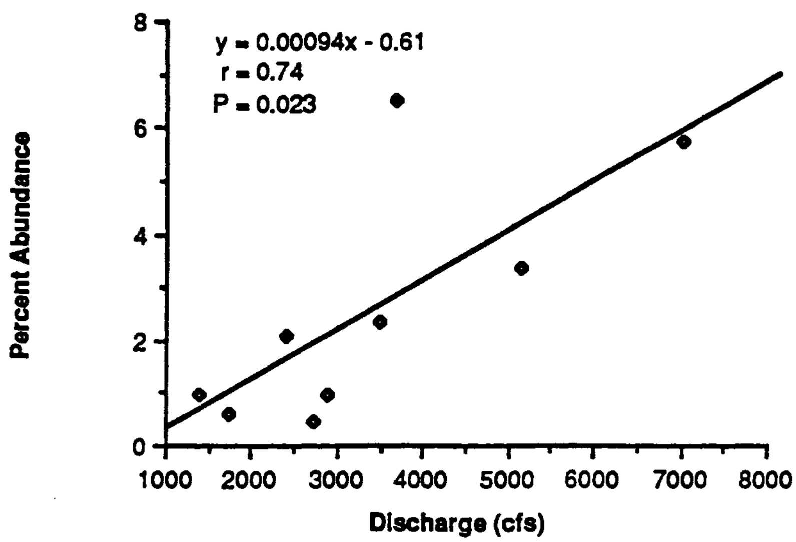

Figure 37. Plot of adult golden redhorse relative abundance versus the mean discharge from July through the sampling period.

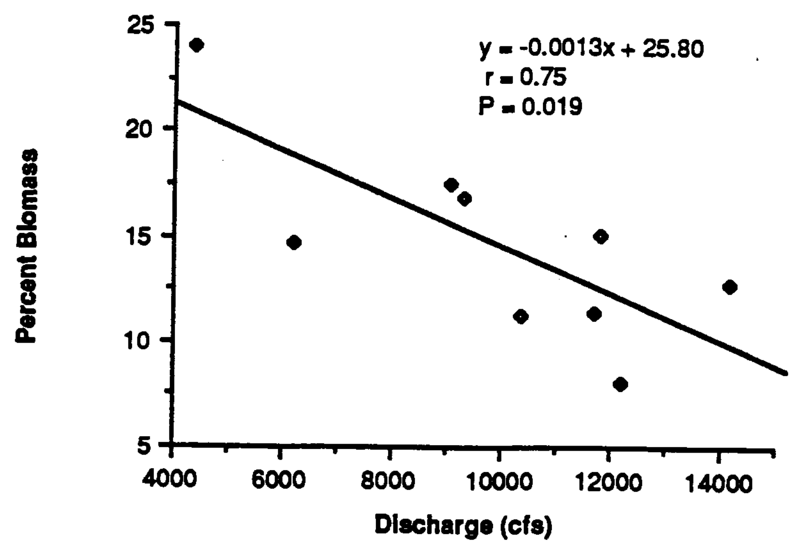

Figure 38. Plot of adult golden redhorse relative biomass versus mean discharge during April.

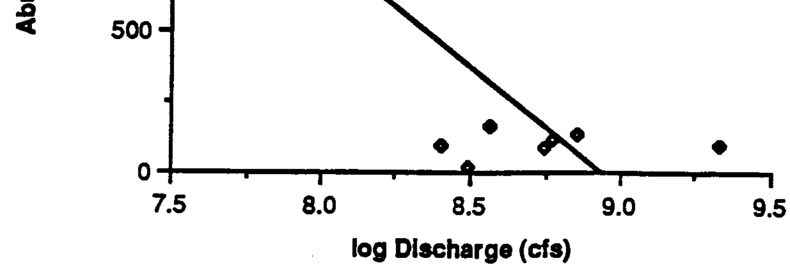

Figure 39. Semi-logarithmic plot of young-of-the-year bluntnose minnow abundance versus the mean discharge from May through the sampling period.

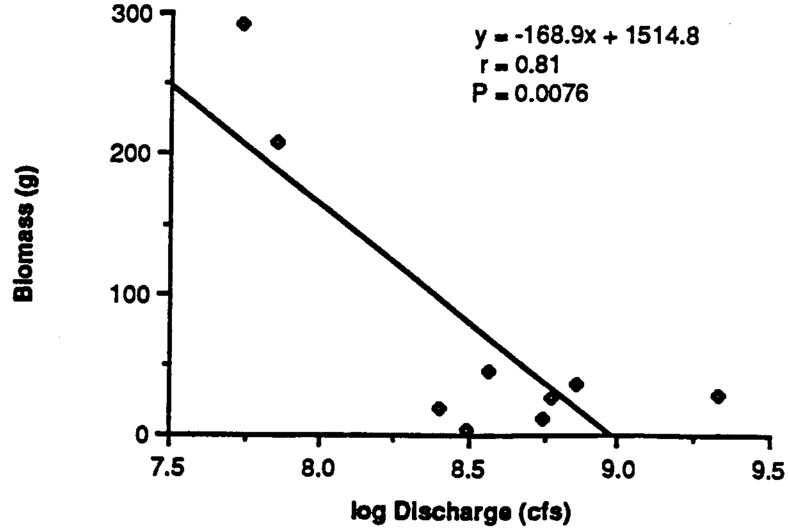

Figure 40. Semi-logarithmic plot of young-of-the-year bluntnose minnow biomass versus the mean discharge from May through the sampling period.

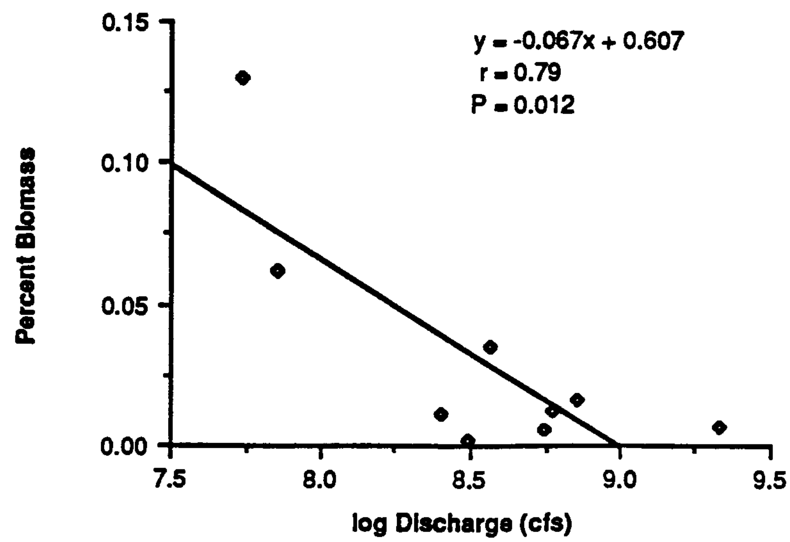

Figure 41. Semi-logarithmic plot of young-of-the-year bluntnose minnow relative biomass versus the mean discharge from May through the sampling period.

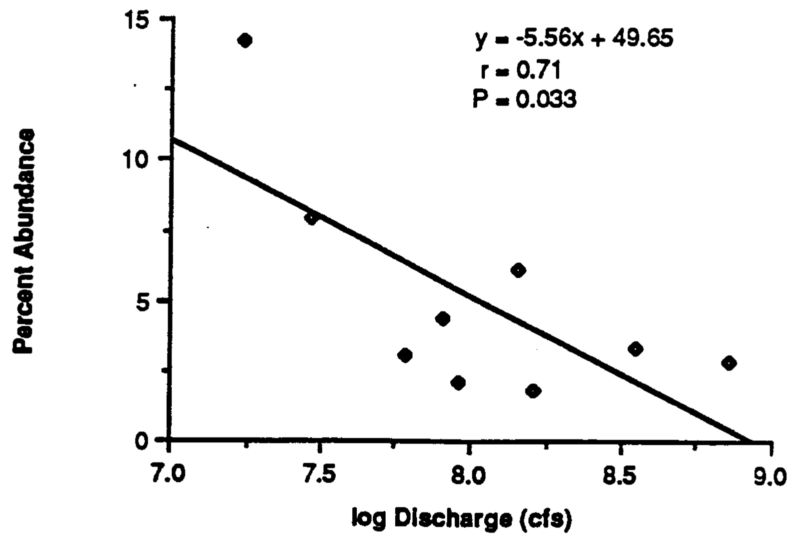

Figure 42. Semi-logarithmic plot of young-of-the-year bluntnose minnow relative abundance versus the mean discharge from July through the collection period.

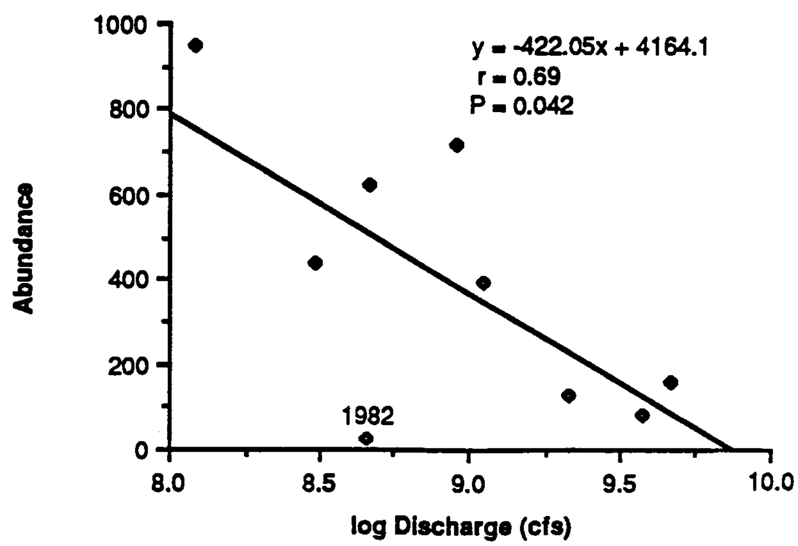

Figure 43. Semi-logarithmic plot of adult bluntnose minnow abundance versus mean discharge during May.

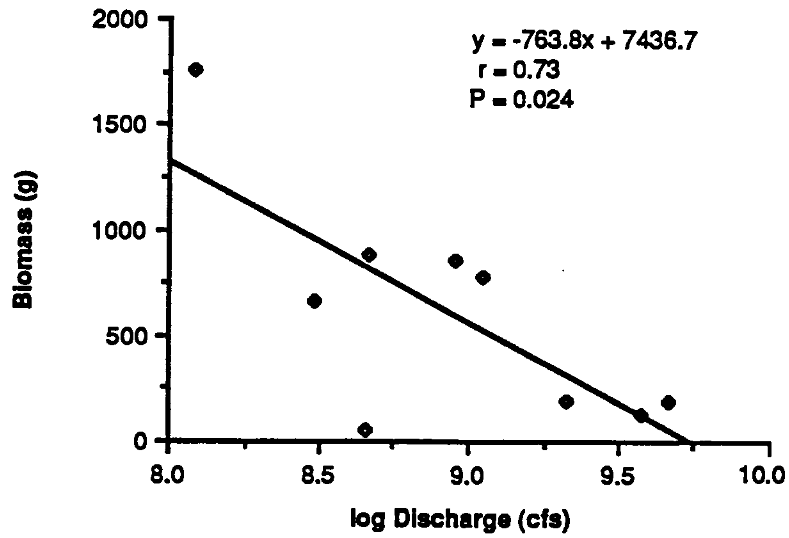

Figure 44. Semi-logarithmic plot of adult bluntnose minnow biomass versus mean discharge during May.